THE IMPLICATIONS OF POPULATION AGING FOR ECONOMIC GROWTH

A REGIONAL COMPARATIVE STUDY

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ABSTRACT

I use a reduced form regression model to determine the extent to which population aging accounts for economic growth in each of the nine regions of the world. Predominantly, I build upon the research of Bloom et al. (2010), which is central to formulating my regression equation. I separate the difference between each region's average growth rate from the world average growth rate into demographic and non-demographic effects using the estimated coefficients. The results suggest that more economically developed regions have potentially benefited from population aging, while less economically developed regions have not.

JEL classification: J14, J21, J26, O10, O40

Keywords: Population Aging, Economic Growth, Economic Policy, Labor-force Participation, Life Expectancy, Retirement Age

I. INTRODUCTION

It is well known that over the next fifty years most developed nations will experience a significant aging of their population. The United Nations recently projected that during this time period the average share of the old-aged population is expected to double in the major industrialized countries (Fougère & Mérette, 1999). In fact, over the past fifty years Japan, as one of the most extreme examples, has already seen significant population aging, with an increase in its old-age share from 5.7% in 1960 to 23.0% in 2010, and a decrease in its youth-age share from 30.2% in 1960 to 13.3% in 2010 (World Development Indicators). It is predicted that these demographic changes will have substantial fiscal and economic consequences (Fougère & Mérette, 1999). Studying the implications of these aging populations on economic growth is therefore a very interesting and relevant subject matter as countries prepare for, and respond to, significant demographic changes.

Rather than focusing on the implications of population aging on economic growth for an individual country, I compare the nine regions of the world: North America, Latin America, Europe, the Middle East & North Africa, Sub-Saharan Africa, South Asia, East Asia, Southeast Asia and Oceania. Not only does this provide necessary cross sectional variation in the data, it provides interesting comparative results, particularly from a policy standpoint. The goal of this empirical study is to construct a reduced form regression model that measures the effect of population aging on economic growth. The results from this regression model are then used to separate each regions growth into demographic and non-demographic components. The overarching question this research paper seeks to answer is: How much of a region's economic growth can be accounted for by its demographic changes? The findings suggest that well-developed regions have potentially benefited from population aging, while less developed regions have not. The discussion focuses on a two-way relationship between population aging and economic growth, rather than a causal relationship.

This paper contributes to and builds on the existing literature. Numerous research papers have used Overlapping Generation (OLG) models to simulate the impacts of population aging on economic growth (Fougère & Mérette, 1999). The most important study upon which my research builds is by Bloom, Canning & Finlay (2010). To my knowledge, their study is the only one to have used a reduced form regression analysis to study the statistical relationship between population aging and economic growth. They undertook their study focused specifically on Asia. The most significant contribution of my research to previous literature is its global focus, as the first study to compare the aging impacts on growth across nine regions of the world.

In Section II of this research proposal I provide a detailed review of the most relevant literature pertaining to this subject matter, in particular to Bloom et al.'s 2010 study. This is followed by Section III, which provides a detailed theoretical framework for my study focused on growth theory and the regression equation formulation. In Section IV, I describe the various data sources that are available for the variables in my analyses. Section V provides a discussion on the empirical specifications and results of my research, followed by Section VI for concluding remarks.

II. Literature Review

Previous empirical studies on population aging and economic growth use either Overlapping Generation (OLG) models or reduced form regression models. In this section I first provide a brief overview of OLG models and the important findings from studies that take this approach. Following this, I discuss in depth the research that uses reduced form regression models since this is the most relevant to my study.

In general, Overlapping Generation (OLG) models are based on the life-cycle theory of savings behavior and model various overlapping generations living side by side at each point in time (Hviding and Mérette, 1998). While many studies use an OLG model with agents living in two periods of life and having an endogenous probability of surviving for a third period (Blackburn & Cipriani, 2002), others use models with up to fifteen overlapping generations (Fougère & Mérette, 1999). Each agent maximizes their utility depending on their preferences over consumption and the number of children, which can vary depending on the study (Zhang et al., 2001). Researchers who focus on population aging and economic growth often modify the OLG model to include endogenous-growth features, which are generally expected to arise from the accumulation of both physical and human capital (Fougère & Mérette, 1999).

There are various important findings from many of these studies. Firstly, in their study of seven OECD countries, Fougère and Mérette (1999) find that future generations could have sufficient incentive to invest more in human capital and in turn increase economic growth, even if there are reductions in saving levels and physical capital returns. Another significant finding is by Zhang et al. (2001), who conclude that fertility, human capital investment and growth are affected by increases in longevity, with the net effect being a decline in fertility, and an incline in both human capital investment and growth. They also find that the level of these effects depends on the relative strength of the tastes for the number and welfare of children (Zhang et al., 2001). Finally, Futagami and Nakajima (2001) find that population aging does not necessarily have a negative impact on economic growth and that the implementation of a policy that postpones the retirement age would have a dampening effect on growth. This analysis remains brief since I do not build on these approaches in my research methodology, but the results are interesting and inform my study.

To my knowledge, there has only been one previous study, by Bloom et al. (2010), that has used a reduced form regression model. For this reason, this study will serve as a key resource for my research, in particular in constructing my regression equation. The authors begin by providing the necessary background of Asia's demographic changes over the study period. This is followed by their regression analysis to find the statistical relationship between the youth-age and old-age shares and economic growth. Finally, they discuss other channels by which age-structure shifts impact economic growth, including behavioral responses and institutional settings.

Bloom et al.'s (2010) study analyzes the time period beginning 1960 and ending 2005. During this time the key drivers of Asia's significant aging population were declining fertility, increased life expectancy and the transitional dynamics of varying cohort sizes moving through the age distribution. For example, the fertility rate in the Republic of Korea plummeted from 5.7 to 1.1 over this time period, and Japan boasts the highest life expectancy in the world. The short-run effects of the declining fertility include a decrease in the youth-age share of the population and an increase in the working-age share of the population. From these effects they derive that GDP (or income) per capita is likely to grow in the short-run. However, the authors focus their attention on the long-run effects stemming from the fertility rate falling below the replacement rate for many Asian countries. In turn, this causes the working-age share to decrease and the old-age share to increase (Bloom et al., 2010).

Based on the results of previous studies, Bloom et al. (2010) hypothesize that the population aging in Asia has positively contributed to economic growth. These studies indicated that one-third of Asia's 'economic miracle' was the result of their huge demographic changes (Bloom et al., 2003). In addition, Kelley and Schmidt (2005) predicted that 44 percent of Asia's income per capita growth could be attributed to its changing age-structure. They attributed these effects predominantly to the decline in fertility, which increased the relative number of people in the working-age category. It is likely that a larger workforce will have increased total output and thus income per capita. By contrast, it had been suggested that a large portion of Africa's economic distress could be accounted for by its lack of demographic change (Bloom & Sachs, 1998).

Since prior studies thoroughly document the effect of the working-age share on economic growth, Bloom et al. (2010) instead focus on the youth-age and old-age shares. This is because, when focusing on the working-age share, the downward forces of the youth and old-age shares are assumed to be symmetric. My study will take the same approach as Bloom et al. (2010), by removing this symmetry and treating the youth and old-age shares separately.

The second major section of Bloom et al.'s study is the derivation of a reduced form regression model to find the empirical relationship between population aging and economic growth. They use the following regression model:

$$\begin{aligned}\ln(y_t) - \ln(y_{t-1}) = {} & \beta_1 y_{t-1} + \beta_2 edu_{t-1} + \beta_3 cap_{t-1} + \beta_4 inst_{t-1} \\ & + \beta_5 c_{t-1} + \beta_6 o_{t-1} \beta_6 \Delta c_t + \beta_6 \Delta o_t + \delta_i + \delta_t + \varepsilon_{it}.\end{aligned}$$

Where,

- $\ln(y_t) - \ln(y_{t-1})$ is economic growth, where y_t is GDP per capita
- *edu* is the education level, calculated as the average years of secondary schooling
- *cap* is the level of the capital stock, calculated by interpolation of capital investment data
- *inst* is the institutional quality, measured by trade openness, the Freedom House Polity Index and other factors that impact labor productivity, such as life expectancy
- *c* is the youth-age share, calculated as the percentage of the population aged 14 years and below, and Δc is the change in the youth-age
- *o* is the old-age share, calculated as the percentage of the population aged 65 years and above, and Δo_t is the change in the old-age share
- δ_i and δ_t are some time invariant country fixed effects, using dummy variables for characteristics such as the fraction of land in the tropics or whether the country is landlocked or not
- ε_{it} is a random error term

The regression provides various interesting results, with the most relevant being the coefficients on the youth and old-age shares. Firstly, the long-run effect on economic growth of an increase in the level of the old-age population share is negative, but not significant. Alternatively, the long-run effect on economic growth of an increase in the level of the youth-age population share is in fact both negative and significant. This implies that a 10% decrease in the youth-age share will cause an increase in economic growth of 2.2%. Both of these main findings of Bloom et al. (2010) are consistent with those of Kelley and Schmidt (2005).

The authors discuss the realities of population aging and the behavioral responses and institutional settings that make the results more complicated (Bloom et al., 2010). These behavioral changes predominantly impact labor supply, savings patterns and education level. Firstly, the change in family structure increases labor supply since the greater portion of elderly people can care for the youth-age, allowing the working-age to work more. Additionally, the decline in fertility increases female labor supply since women have fewer children to care for. Secondly, savings patterns change as life expectancy, income potential, and expenditure requirements change. Previous studies that focus on the link between national savings rates and demographic structure suggest that much of East Asia's savings boom can be attributed to its population's changing age structure (Higgins, 1998). Thirdly, there is much evidence showing that as the population ages the working-age share increases their investment in education for the youth-age share. Lastly, there are country specific institutional factors involved, in particular issues surrounding who will support the elderly: the state through social security, individual retirement savings, or the labor supply of the elderly themselves. Combining the changes in demographic variables, behavioral responses and institutional factors, the authors find that aging has an ambiguous effect on economic growth (Bloom et al., 2010).

My research builds on Bloom et al.'s 2010 study, since it is the only research that has used a reduced form regression model to test the statistical relationship between population aging and economic growth. In the first part of my study, I adopt their regression model, while making several minor adjustments. Rather than focusing solely on Asia however, the model is used to study nine regions of the world. This is the major contribution that my study makes to existing literature, since it is the first at a global level. A study of this nature is important since it allows the results for each region of the world to be compared. These regions differ widely in terms of economic development, political freedoms and human rights. Furthermore, the use of a reduced form regression model rather than an OLG model makes such an expansive regional comparison possible within the time frame of the research. The second part of my study extends beyond this regression model and uses a mathematical equation to answer the question: How much of a region's economic growth can be accounted for by its population aging?

III. Theoretical Framework

Understanding economic growth theory is crucial for constructing the methodology of my research. In this section I firstly provide an overview of the Solow-Swan Model and Growth Accounting, in order to understand the basic drivers of economic growth and how population aging impacts these drivers. This is followed by the theories used by Bloom et al. (2010) to determine the initial regression model, which also informs my regression model.

In 1956, Robert Solow and Trevor Swan derived an exogenous growth model, which we call the Solow-Swan Model (Barro & Sala-i-Martin, 2004). The core of their neoclassical model is a production function with the basic form:

$$Y(t) = F[K(t), L(t), T(t)]$$

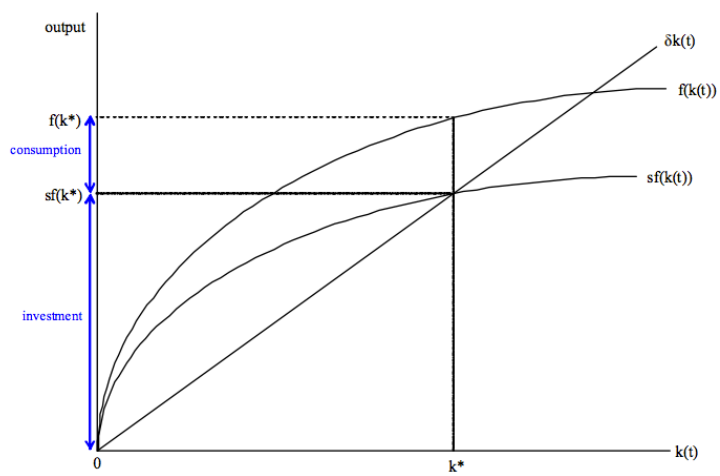
Where, *Y(t)* is the flow of output produced at time *t, K(t)* is the capital stock (durable physical inputs) at time *t, L(t)* is the quantity of labor at time *t,* and *T(t)* is the level of knowledge or technology at time *t.* In other words, the Solow-Swan model tells us that the level of output in an economy is a function of capital, labor and technology (Barro & Sala-i-Martin, 2004). The production function is often assumed to take the Cobb-Douglas form, since it is thought to provide a reasonable description of actual economies. It takes the form:

$$Y = AK^{\propto}L^{1-\propto}$$

Where $A>0$ is the level of technology, and α is a constant between zero and one (Barro & Sala-i-Martin, 2004).

This neoclassical production function has the following properties: constant returns to scale, positive and diminishing returns to private inputs, Inada conditions and essentiality (Barro & Sala-i-Martin, 2004). Figure 1.1 shows such a production function expressed in intensive form, or per capita form.

Figure 1.1: Solow-Swan Model



Source: Acemoglu, D. (MIT)

Growth accounting is an empirical methodology originating from the Solow-Swan production function (Barro & Sala-i-Martin, 2004). It allows GDP growth to be broken into changes in factor inputs and production technologies. The following growth accounting equation is found by taking logarithms and derivatives of the production function:

$$\frac{\dot{Y}}{Y} = g + s_K \frac{\dot{K}}{K} + s_L \frac{\dot{L}}{L}$$

In this equation $\dot{Y}/Y$ is the derivative representing the growth rate of GDP, g is the growth rate of technological change, $\dot{K}/K$ is the derivative representing the growth rate of capital stock and $\dot{L}/L$ is the derivative representing the growth rate of labor. In addition, s_K is the fraction of GDP used to pay rent capital (the capital share), and s_L is the fraction of GDP used to pay wages (the labor share). In this form, it is also assumed that factor markets are competitive. As such, this equation tells us that the growth rate of GDP can be decomposed into the growth rate of capital, labor and technology (Barro & Sala-i-Martin, 2004).

Since s_K and s_L can be estimated empirically, g is determined as the residual or difference between the growth rate of GDP and the part of the growth rate that can be accounted for by capital and labor growth. The following equation is rearranged to solve for $\hat{g}$, which is known as *Total Factor Productivity (TFP)* growth or the *Solow Residual* (Barro & Sala-i-Martin, 2004):

$$\hat{g} = \frac{\dot{Y}}{Y} - s_K \frac{\dot{K}}{K} - s_L \frac{\dot{L}}{L}$$

Understanding the Solow-Swan Model and Growth Accounting is important when considering the impacts of population aging on economic growth. The production function and growth accounting formula make clear that GDP can only grow if there is growth in productive inputs – capital, labor and the level of technology (or TFP) (Barro & Sala-i-Martin, 2004). When examining the long-run demographic changes of an aging population - that is, an increase in the old-age share and a decrease in the youth-age share - it is expected that economic growth would decline (Bloom et al., 2010). This is because population aging is expected to cause a decrease in both the labor supply per capita, which decreases the labor variable, and savings per capita, which decreases the capital variable. However, as previously discussed in the literature review, when including both behavioral responses and institutional factors, the overall impact on economic growth is ambiguous (Bloom et al., 2010).

Other relevant theory for this study is that used by Bloom et al. (2010) in the construction of their reduced form regression model. It is particularly important since their regression equation is used as the starting point for mine. They use the convergence model framework of Bloom & Canning (2008), and divide the population into youth-age, *C*, working-age, *WA*, and old-age, *O*. Firstly, they characterize growth of GDP per worker as the distance from steady state:

$$(1) \qquad g_z = \lambda(z^* - z_0)$$

Where z^* is GDP per worker at time *t,* and z_0 is the steady state GDP per worker. They refer to Barro and Sala-i-Martin's (2004) discrete time models which find a log-linearization around the steady state, where $z = log(Y/L)$. Additionally, since there is a vector of variables, *X,* that can affect the steady-state level of labor productivity, this equation becomes:

$$(2) \qquad g_z = \lambda(X\beta - z_0)$$

In order to include the age structure with this theory of convergence, the authors use the following relationship used in Bloom and Canning (2008):

$$(3) \qquad \frac{Y}{N} = \frac{Y}{L}\frac{L}{WA}\frac{WA}{N}$$

Where *Y* is GDP, *N* is the total population, *WA* is the number of people in the working age, and *L* is the number of people participating in the labor force. The authors then assume that the working-age share represents the age structure and that the participation rate is constant, and break down the growth of income per capita in the following way:

$$(4) \qquad g_{Y/N} = g_{Y/L} + g_{WA/N}$$

At this point, equation (2) can explain growth of income per worker, $g_{Y/L}$. The authors then determine the growth of the working-age share, $g_{(WA/N)}$. Since the working-age is the population less the youth-age and old-age population, the equation becomes:

(5) $$g_{Y/N} = g_{Y/L} + g_{(N-C-O)/N}.$$

They firstly use the difference of logs to approximate the working-age share growth:

(6) $$g_{WA/N} \approx \ln\left(\frac{WA}{N}\right)_t - \ln\left(\frac{WA}{N}\right)_0.$$

This growth equation is then redefined so that *WA=N-C-O:*

(7) $$g_{(N-C-O)/N} = \ln\left(\frac{N-C-O}{N}\right)_t - \ln\left(\frac{N-C-O}{N}\right)_0.$$

Using the approximation, ln(1-x) ≈ x, for the increasing working-age share, they assert that:

(8) $$g_{(N-C-O)/N} = -\left(\frac{C+O}{N}\right)_t + \left(\frac{C+O}{N}\right)_0$$
$$g_{(N-C-O)/N} = \frac{C}{N_0} - \frac{C}{N_t} + \frac{O}{N_0} - \frac{O}{N_t}.$$

They label each of the following:

(9) $$y = \log\left(\frac{Y}{N}\right), z = \log\left(\frac{Y}{L}\right), w = \log\left(\frac{WA}{N}\right)$$

And find that $y = z + w$ by taking the logarithms of equation (3).

Finally, they substitute these derived formulas into the income per capita growth equation above:

$$(10) \qquad g_{Y/N} = \lambda(X\beta - z_0) + \frac{C}{N_0} - \frac{C}{N_t} + \frac{O}{N_0} - \frac{O}{N_t}$$

$$g_{Y/N} = \lambda(X\beta + w_0 - y_0) + \frac{C}{N_0} - \frac{C}{N_t} + \frac{O}{N_0} - \frac{O}{N_t}$$

$$g_{Y/N} = \lambda\left(X_0\beta - \frac{C}{N_0} - \frac{O}{N_0} - y_0\right) - \left[\frac{C}{N_t} - \frac{C}{N_0}\right] - \left[\frac{O}{N_t} - \frac{O}{N_0}\right]$$

$$g_{Y/N} = \left(X_0\beta_0 + \beta_1\frac{C}{N_0} + \beta_2\frac{O}{N_0} + \beta_3 y_0\right) + \beta_4\Delta\frac{C}{N_t} + \beta_5\Delta\frac{O}{N_t}.$$

The authors find that this final equation can be used to estimate the effects of youth-age and old-age dependency on growth of income per capita. Included in this equation are the explanatory variables, *X*, that describe the level of GDP per worker. These include the capital stock, education, institutional quality and other variables that impact labor productivity. Thus the estimated regression equation is:

$$(11) \qquad \ln(y_t) - \ln(y_{t-1}) = \beta_1 y_{t-1} + \beta_2 edu_{t-1} + \beta_3 cap_{t-1} + \beta_4 inst_{t-1} + \beta_5 c_{t-1} + \beta_6 o_{t-1}\beta_6\Delta c_t + \beta_6\Delta o_t + \delta_i + \delta_t + \varepsilon_{it}.$$

This is the equation I use in the first part of my methodology, although I remove both the capital stock, *cap,* and the country fixed effects, δ_i. Firstly, I take the theoretical reasoning from the research of Mankiw, Romer and Weil (1992) for removing capital stock from the growth equation. In their paper they derive an empirical formula for income per capita that does not rely on the level of capital stock, given that initial income is also included on the right hand side of the regression equation. Furthermore, I remove country fixed effects, as country variations are relevant to the comparative nature of my study. In other words, I am interested in how country-specific features of the data affect growth.

IV. DATA

Table 1.1 provides a set of descriptive statistics for each variable in my operational dataset including means, standard deviations, minimums and maximums. The table shows the significant variation that exists across countries and through time, especially when comparing the minimum and maximum values for each of the variables. A noticeable example of this is for the life expectancy variable, which has a mean value of 62 years, a minimum of 24 years and a maximum of 83 years. The table also shows the expected demographic changes of an aging population, with an average decrease in the youth-age share and an average increase in the old-age share. Additionally, Table 1.2 provides a list of the countries separated into their regions that are included in the dataset.

The data for my regression analysis was available from a variety of sources. The first source of data was the Penn World Tables 7.1, which provides purchasing power parity and national income accounts converted to international prices for 189 countries from 1950-2010. By converting expenditure entries into a common set of prices in a common currency, the tables allow users to compare 'real' quantities, between countries and over time. These tables were used for attaining data for the GDP per capita variable and for the trade openness variable, which used a calculation involving imports and exports.

The second data source was the World Development Indicators produced by the World Bank, which provide the most accurate global development data. This was used primarily for demographic data for the following variables: youth-age share, old-age share, change in youth-age share, change in old-age share, and life expectancy.

The third data source was from Barro and Lee (2001), which provides three different education datasets to choose from: education attainment for population aged 15 years and over, education attainment for population aged 25 years and over, and education attainment by age group. For the education variable in this study I use the education attainment for the population aged 15 years and over, which is described as the average years of secondary school education, since it was effective in the study of Bloom et al. (2010).

Finally, the Freedom House Polity Index was used for the political freedom variable within the institutional quality variable. Freedom House is a non-governmental organization in the United States that assesses each country's degree of political freedoms and civil liberties. This was simply collected online and was calculated by subtracting the degree of autocracy from the degree of democracy.

It is clear from the above sources that data were widely available for the variables in my regression model. More importantly, there are many countries included in the datasets from within the nine regions, which provides me with a rich cross section of data. Upon closer examination of the data there is also a significant range of countries represented: high to low income, low to high fertility rates, low to high infant mortality rates, etc.

Table 1.1 Descriptive Statistics

Variable	**Mean**	**Standard Deviation**	**Min**	**Max**
Five-year growth rate of GDP per capita	0.02	0.03	-0.23	0.24
Log real GDP per capita	8.36	1.33	5.08	11.08
Education (average years of secondary schooling)	1.90	1.28	0.06	6.18
Trade openness	73.27	47.92	8.32	430.56
Freedom House Polity Index	3.77	2.21	1.00	7.00
Life expectancy	64.32	11.03	23.73	81.93
Youth-age share %	35.14	10.47	13.66	52.10
Old-age share %	6.35	4.51	0.83	19.85
Youth-age share change %	-1.30	1.51	-8.85	3.31
Old-age share change %	0.33	0.51	-1.56	3.12

A limitation of the data is that not every country has data for each of the variables for every year since 1960. The implications are that if a given year for a particular country does not have data for every variable, then the entire year for that country will be removed from the regression analysis. These missing data points correspond, in many cases, to less developed countries in the early part of my sample period.

There are two additional notes that should be made regarding the variables for the regression model. Firstly, to represent the institutional quality of nations and variables that impact labor productivity, the following variables are used: trade openness, Freedom House Polity Index and life expectancy. I also note that capital stock data are only available from the World Development Indicators from 1950 to 1980 for 64 countries. Furthermore, these series have been discounted due to difficulties associated with their calculation and underlying modeling assumptions. In the Solow model, discussed earlier, the capital stock is an important driver of economic growth. However, I use the findings of Mankiw, Romer and Weil (1992), who show that the inclusion of capital stock for a country is not necessary in the formula for economic growth, as long as initial income is included as a right-hand side variable.

Table 1.2 Country Summary

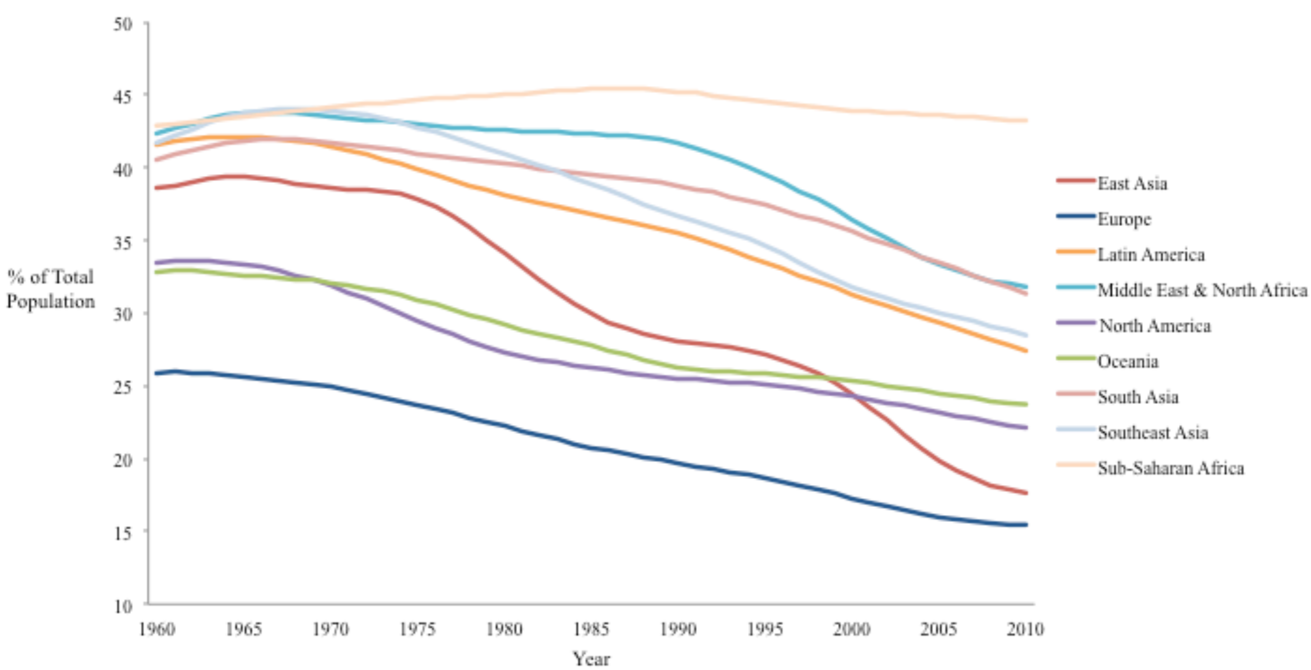
East Asia	Europe	Latin America	Middle East & North Africa	North America	Oceania	South Asia	Southeast Asia	Sub-Saharan Africa
China	Austria	Argentina	Algeria	Canada	Australia	Afghanistan	Brunei Darussalam	Angola
Hong Kong	Belgium	Belize	Bahrain	Mexico	Fiji	Bangladesh	Cambodia	Burundi
Japan	Bulgaria	Bolivia	Cyprus	United States	New Zealand	India	Indonesia	Benin
Korea, Rep.	Croatia	Brazil	Egypt, Arab Rep.		Papua New Guinea	Maldives	Lao PDR	Botswana
	Czech Republic	Chile	Iran, Islamic Rep.		Tonga	Nepal	Malaysia	Cameroon
	Denmark	Colombia	Iraq			Pakistan	Philippines	Central African Republic
	Spain	Costa Rica	Israel			Sri Lanka	Singapore	Congo, Dem. Rep.
	Estonia	Cuba	Jordan				Thailand	Congo, Rep.
	Finland	Ecuador	Libya				Vietnam	Comoros
	France	El Salvador	Morocco					Cote d'Ivoire
	Germany	Guatemala	Mali					Gabon
	Greece	Guyana	Mauritania					Gambia, The
	Hungary	Honduras	Niger					Ghana
	Ireland	Jamaica	Saudi Arabia					Kenya
	Italy	Nicaragua	Sudan					Lesotho
	Netherlands	Panama	Senegal					Liberia
	Norway	Peru	Tunisia					Malawi
	Poland	Paraguay	Turkey					Mauritius
	Portugal	Uruguay	United Arab Emirates					Mozambique
	Romania	Venezuela, RB	Yemen, Rep.					Namibia
	Slovak Republic							Rwanda
	Slovenia							Sierra Leone
	Sweden							Swaziland
	Switzerland							Tanzania
	United Kingdom							Togo
								Uganda
								South Africa
								Zambia
								Zimbabwe

V. Empirical Specification

Population Aging Graphed

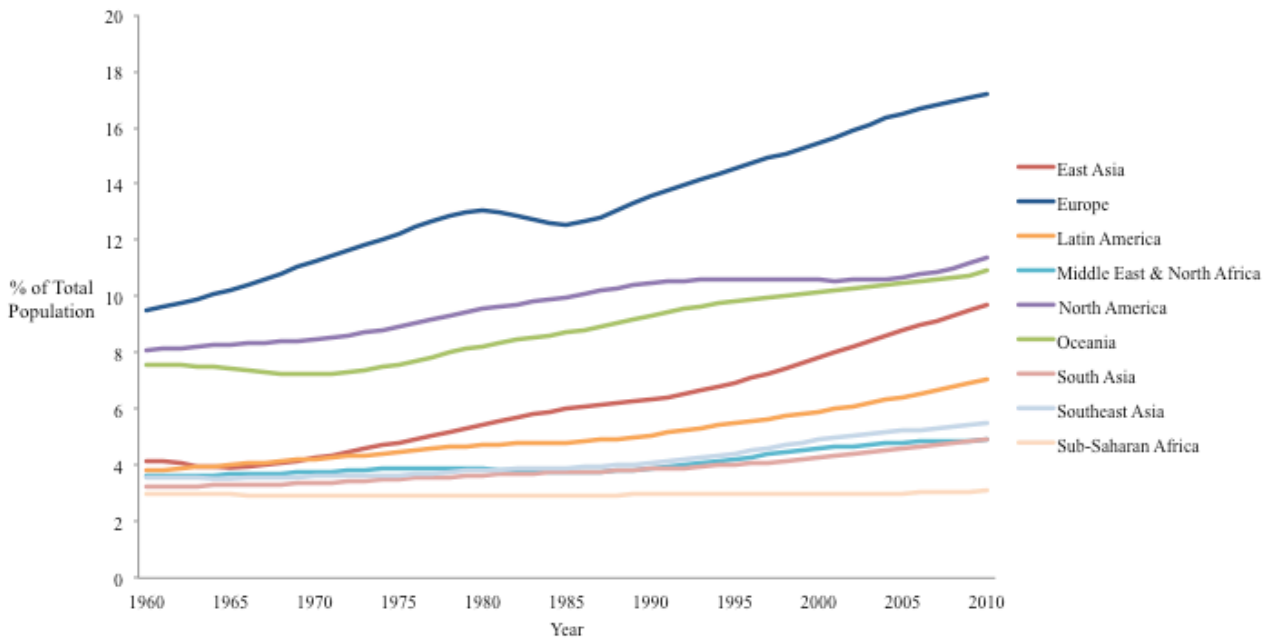
To begin a discussion of the empirical specification of the study, I have created graphs showing the weighted average aging and economic growth in each region. These are useful for understanding the general trends of the youth-age, working-age and old-age shares of the populations in each region from 1960-2010, and also how these compare to growth performance during this time period. Figures 1.2, 1.3 and 1.4 show the youth-age, old-age, and working-age shares, respectively, for each region between the years 1960 and 2010.

Figure 1.2: Youth-Age Population Share (Years 0-14) from 1960-2010 by Region



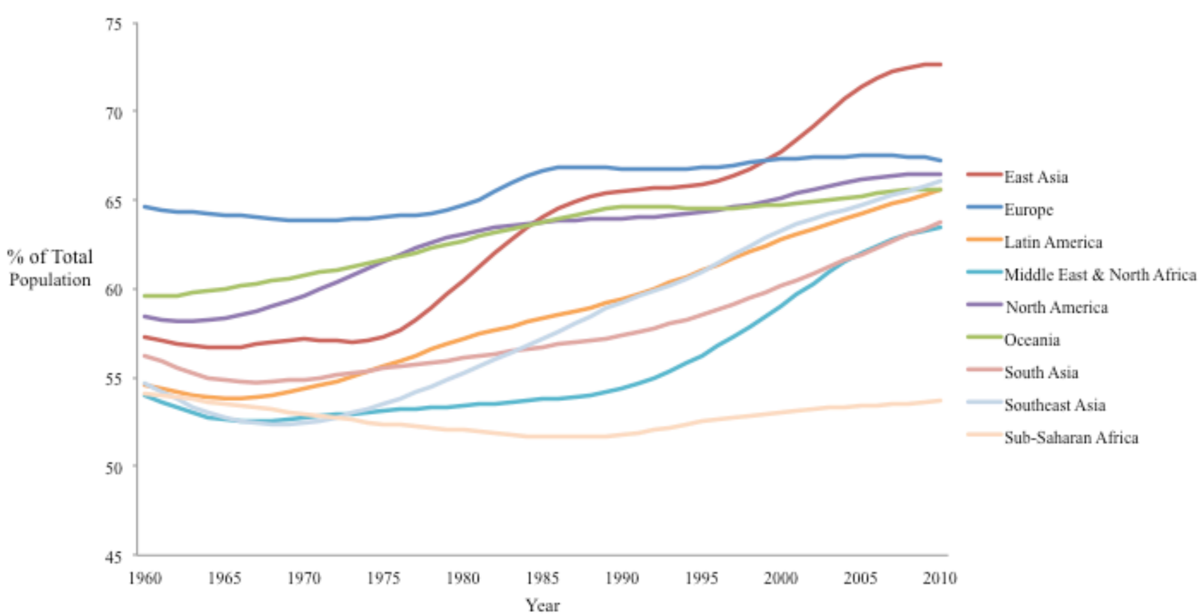
Data Source: World Development Indicators, *World Bank*

Figure 1.3: Old-Age Population Share (Years 65+) from 1960-2010 by Region



Data Source: World Development Indicators, *World Bank*

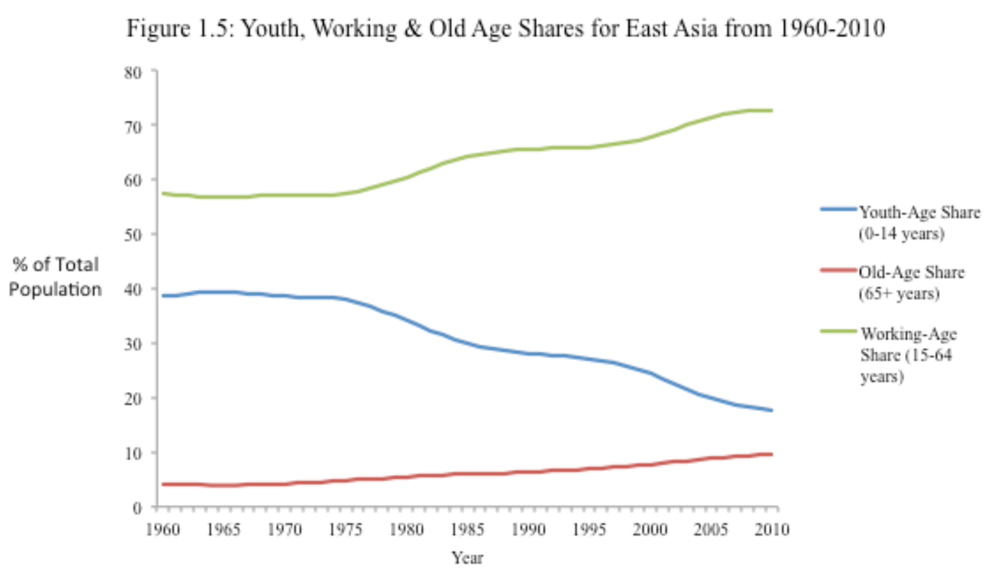
Figure 1.4: Working-Age Population Share (Years 15-64) from 1960-2010 by Region



Data Source: World Development Indicators, *World Bank*

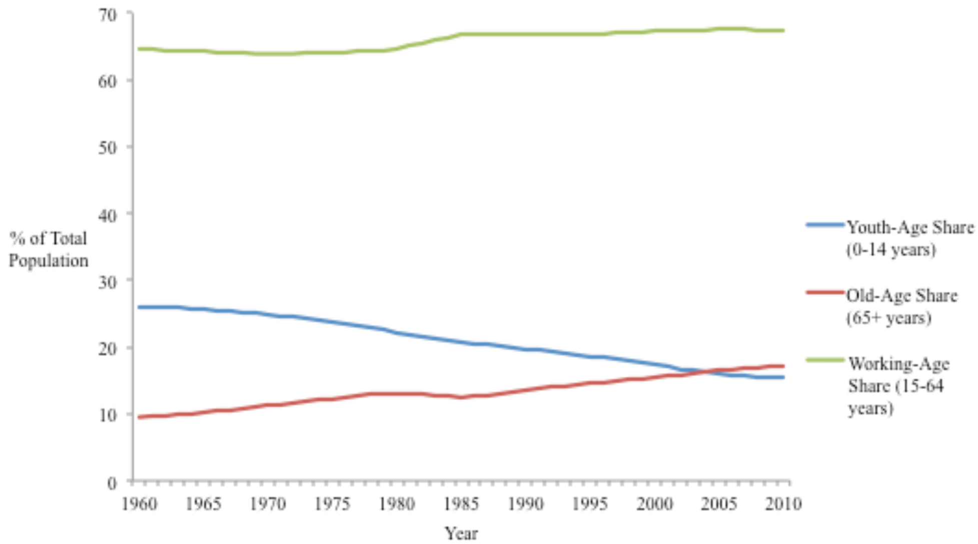
The above graphs show that all regions are experiencing a decline in the youth-age share of their populations and an incline in both the old-age and working-age shares of their populations. In other words, their populations are aging. The extent of these demographic changes differs significantly between regions, with East Asia and Europe experiencing the most extensive changes. The following two graphs, Figures 1.5 and 1.6, show the demographic trends specifically for each of these regions over the 50-year period.

These charts show that for both East Asia and Europe, the old-age shares essentially double and the youth-age shares halve. In fact, Europe experiences a complete shift in their age structure, where the old-age share of the population actually overtakes the youth-age share. Since East Asia's development lags that of Europe, we could predict that the same trend will occur in the future for East Asia, as we see these two lines in the chart moving closer together. It is clear that there are significant demographic changes occurring in all regions, in particular for East Asia and Europe, and this study will determine to what extent these changes affected the level of economic growth.



Data Source: World Development Indicators, *World Bank*

Figure 1.6: Youth, Working & Old Age Shares for Europe from 1960-2010

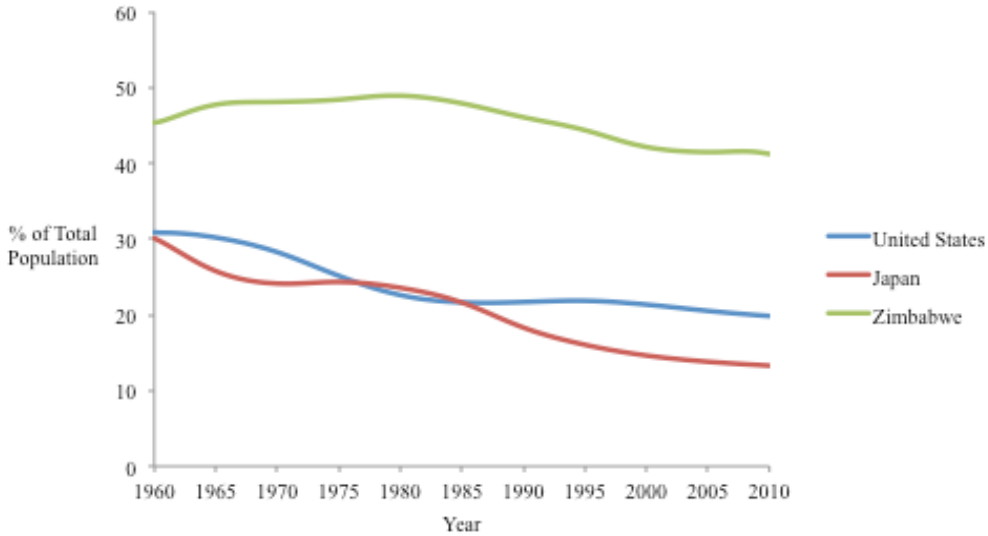


Data Source: World Development Indicators, *World Bank*

The average population shares for each region in the above charts were calculated by weighting each nation by its population share in each year. Unfortunately, this potentially masks some of the aging that is occurring at the individual country level. For example, Japan's old age share has increased from 5.7% in 1960 to 23.0% in 2010, although the above graph only shows an increase from 4.2% to 9.7% in the respective years in the region of East Asia. This is due to China's overpowering population share in the region.

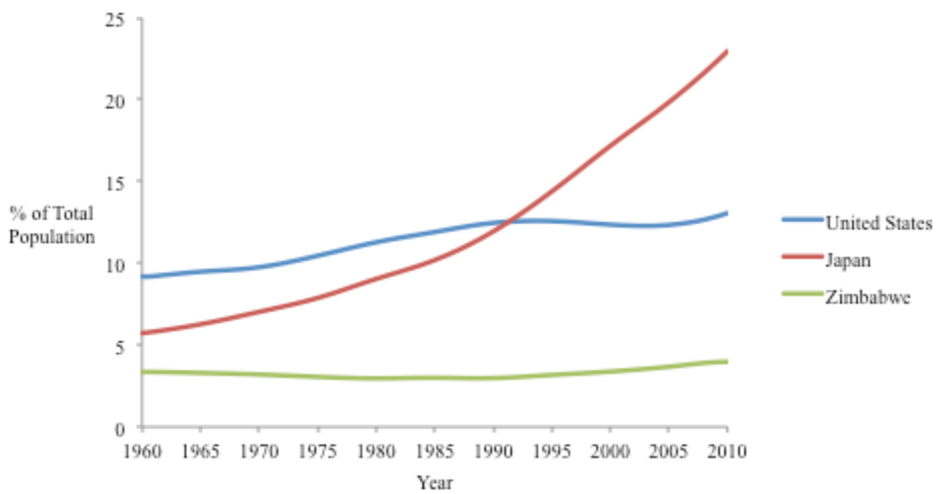
It is interesting to also look at population aging at the country level, since it puts into perspective the demographic changes that are occurring in countries we are all familiar with. For this reason I have graphed in Figures 1.7 and 1.8 the youth and old-age share changes over the fifty-year period for the United States, Japan and Zimbabwe. These are three countries in completely different regions of the world, and reflect the same comparative aging trends as the regional charts.

Figure 1.7: Youth Age Population Share (Years 0-14) from 1960-2010 for the United States, Japan & Zimbabwe



Data Source: World Development Indicators, *World Bank*

Figure 1.8: Old-Age Population Share (Years 65+) from 1960-2010 for the United States, Japan and Zimbabwe

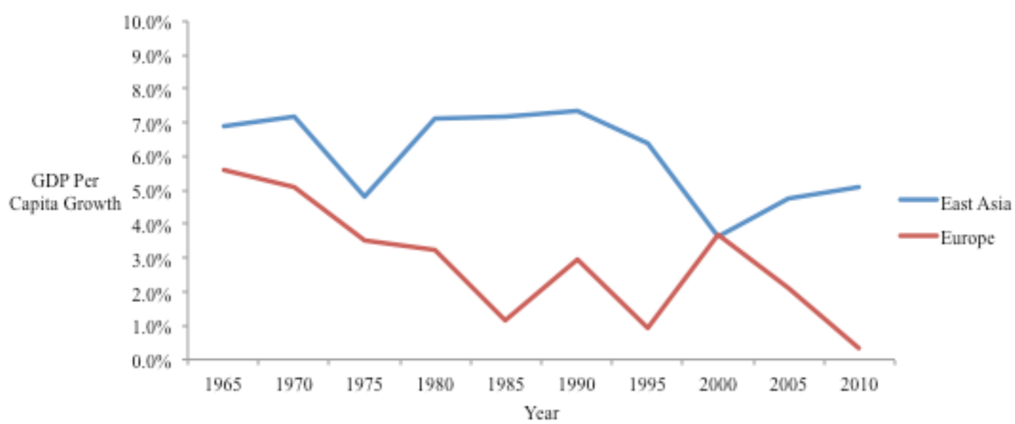


Data Source: World Development Indicators, *World Bank*

These charts show that, of the three countries, Japan experienced the most extensive population changes between 1960 and 2010. Its youth-age share effectively halved, and its old-age share increased to four times its original share of the population. The United States also saw population aging, but to a lesser extent over the fifty year period. Finally, Zimbabwe experienced relatively little, if any changes in its youth and old-age shares. Each of these trends is in line with the regional trends in Figures 1.2 and 1.3.

Figure 1.9 shows the average GDP growth per capita for East Asia and Europe from 1960 to 2010. It shows that this growth fluctuates significantly throughout the 50-year period, but there seems to be a general downward trend, especially for Europe. How much of this can be attributed to the population aging occurring in these regions, as seen in the previous graphs, is the goal of this empirical study.

Figure 1.9: Average GDP Growth Per Capita for East Asia & Europe from 1960-2010



Data Source: Penn World Tables, 7.1

Empirical Approach

Using regression analysis, I seek to answer the following research question: How much of the economic growth in each region can be explained by population aging? The first step in this approach requires running one 'world' regression model that uses data from all 122 countries. As the second step in this approach, I can then use the resulting demographic coefficients in a formula for each region that separates the economic growth into demographic and non-demographic effects.

Empirical Model

As previously discussed, I begin by using the regression equation of Bloom et al. (2010), but remove the capital stock variable and the country fixed effects. As such, the following regression model will be used to determine the statistical relationship between population aging and economic growth:

$$\ln(y_{it}) - \ln(y_{it-1}) = \beta_1 \ln(y_{it-1}) + \beta_2 edu_{it-1} + \beta_3 inst_{it-1} + \beta_4 c_{it-1} + \beta_5 o_{it-1} + \beta_6 \Delta c_{it} + \beta_7 \Delta o_{it} + \delta_t + \varepsilon_{it}$$

The variables are as follows:

Dependent Variable

$\ln(y_{it}) - \ln(y_{it-1})$: Economic growth, change in GDP per capita

Independent Variables

$\ln(y_{it-1})$: Natural log of GDP per capita

edu: Average years of secondary schooling

$inst$: Institutional quality

c: Youth-age share

o: Old-age share

Δc: Change in youth-age share

Δo: Change in old-age share

δ_t: Time fixed effects

ε_{it}: Residual/Error term

In order to remove short-term business cycle effects I treat the natural time period for the model as five years. This five-year time period is used for each of the variables, such that the first time period begins in 1960, the second in 1965 and so forth.

This regression model is essentially showing that I, along with previous researchers, believe that education (human capital), institutional quality and variables that influence labor productivity are sufficient in explaining differences in economic growth across countries and time. Under this assumption, this study is able to determine the degree to which demographic changes also play a role in economic growth.

The second part of the methodology involves using the following equation that separates the variables into demographic and non-demographic effects for each region separately. The equation uses Southeast Asia as an example:

$$(\bar{y}_{SEA} - \bar{y}_{World}) = \sum_{J\ dem.} \widehat{\beta}_J \left(\bar{x}_J^{SEA} - \bar{x}_J^{World}\right) + \sum_{i\ non-dem.} \widehat{\beta}_i \left(\bar{x}_i^{SEA} - \bar{x}_i^{World}\right) + \bar{e}^{SEA}$$

It can be seen that the demographic and non-demographic variables have been separated using the relevant estimated coefficients from the regression results. The results from the above equation are displayed in a bar chart enabling comparison between regions. As such, this equation can be used to answer the research question: How much of the economic growth in each region can be accounted for by population aging?

Results

Table 1.3 provides the results from the world regression equation, which include: the estimated coefficients on the independent variables, the level of statistical significance, and key additional regression statistics.

Table 1.3: Regression Results

Independent Variable	Coefficient Estimate[a]	Standard Error
ln(GDP per capita)	-0.0191***	0.0019
Education	-0.0002	0.0017
Trade Opennness	0.0001***	0.0000
Freedom House Polity Index	-0.0019***	0.0007
Life Expectancy	0.0017***	0.0002
Youth-Age Share	-0.0016***	0.0003
Old-Age Share	-0.0015**	0.0006
Δ Youth-Age Share	-0.0019**	0.0009
Δ Old-Age Share	-0.0039	0.0028
Intercept	0.1354***	0.0251
R^2	0.1838	
F	19.36	
N	790	

a. The parameters reported are least squares coefficient estimates of a linear regression model
* Coefficient estimate is statistically significant at 0.10 level
** Coefficient estimate is statistically significant at 0.05 level
*** Coefficient estimate is statistically significant at 0.01 level

The independent variables that directly relate to the research question are the demographic variables: Youth-Age Share, Old-Age Share, Change in Youth-Age Share, and Change in Old-Age Share. The results show that the youth-age share coefficient, with a value of -0.0016, is statistically significant at the one percent level. I employ a thought experiment to better interpret and understand this coefficient. If a country's youth-age share declined by 10 percentage points over a 50-year period, this would have resulted in a 0.32% increase in economic growth[1]. This is a reasonable and relevant estimate since the youth-age share in the United States declined by 11 percentage points (Penn World Table 7.1) over this time period. This result is interesting since it is at odds with the growth accounting hypothesis, that population aging has negative impacts on economic growth. This finding is however relevant to the findings of Bloom et al. (2010) who also found that a decreasing youth-age share has positive impacts on economic growth. The most likely cause for this finding is that there are fewer youth-aged individuals who are dependent on the working-age population. A closely related variable is the change in youth-age share, which is statistically significant at the five percent level. This tells us that the amount of the youth-age share decline between two periods affects the size of the economic growth effect.

The estimated coefficient on old-age share, with a value of -0.0015, is statistically significant at the five percent level. If interpreted again using the same thought experiment, a 10 percentage point increase in the old-age share of a country over the 50-year period, would result in a decrease in economic growth of 0.3%[2]. This result is in line with the findings of Bloom et al. (2010) who found the coefficient on old-age share to be negative but not significant. There are many explanations for such a result. Firstly, it is likely that a higher old-age share is draining the income and savings from the working-age share, especially as they require additional healthcare. The result of this drain is less capital available for investment in productive assets, either physical capital stock or education. Additionally, as the old-age share increases the subsequent result is a declining work-force, thus reducing output per person.

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[1] Economic growth calculation: $(ln(y_t) - ln(y_{t-1}))/5 = (-0.0016 * (-10))/5$

[2] Economic growth calculation: $(ln(y_t) - ln(y_{t-1}))/5 =(- 0.0015 * (10))/5$

Other interesting results include the coefficients on trade openness and life expectancy, each of which is statistically significant at the one percent level. Using the same thought experiment that was used to interpret the demographic coefficients, an increase in trade openness of 50 percentage points (the change, according to the Penn World Table 7.1, that was experienced by Germany over the 50 year period) would result in an increase in economic growth of 0.1%[3]. Furthermore, if considering an incline in life expectancy of 26 years, the coefficient implies an increase in economic growth of 0.88%[4]. Again, this thought experiment is relevant to the countries in the study, since Peru experienced this exact incline in their life expectancy over the 50 year period, from 48 years in 1960 to 74 years in 2010 (Penn World Table 7.1).

The first result for trade openness seems reasonable, since greater trade capabilities, both internal and external, are drivers of economic growth. However, the result for life expectancy is somewhat surprising and raises questions as to why a higher life expectancy increases economic growth. A possible answer could be that a greater life expectancy has come about through more advanced healthcare, and thus makes the entire population, and in particular the workforce, more productive. Another reason could be that people are now continuing to work until an older age, which contributes to a larger workforce and higher total output.

The results of the second part of the methodology are shown in Figure 1.10. It separates each region's growth difference from the world average into demographic, non-demographic and regional residuals.

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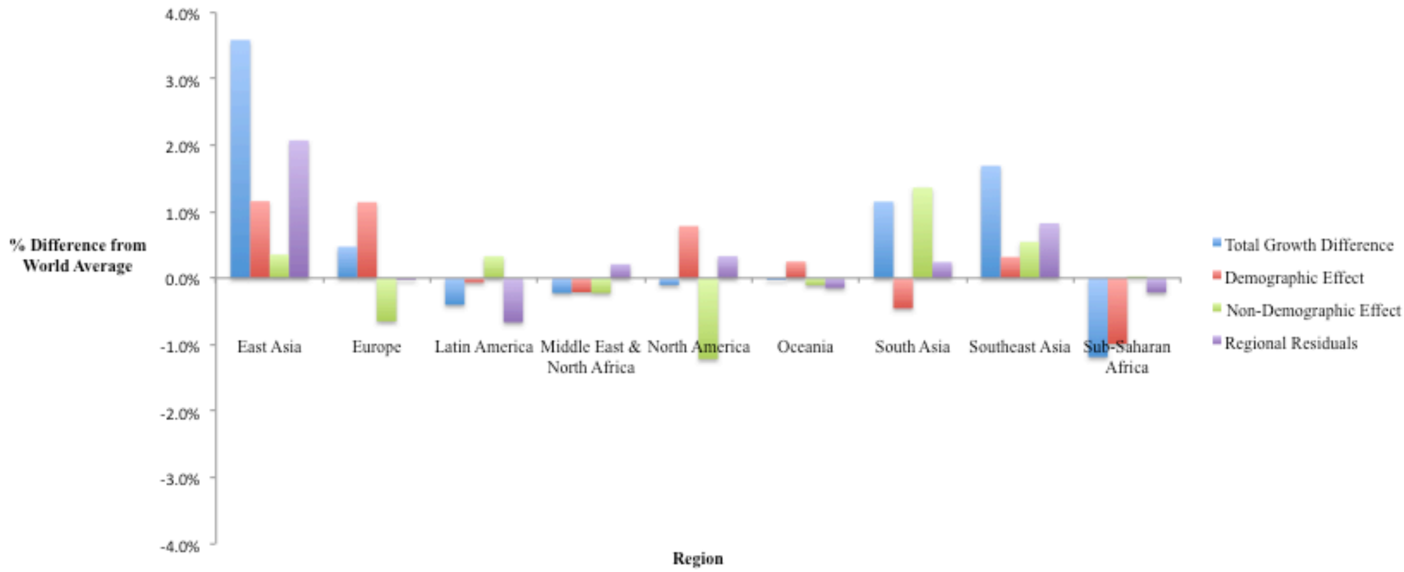
[3] Economic growth calculation: $(ln(y_t) - ln(y_{t-1}))/5 = (0.0001 * (50))/5$
[4] Economic growth calculation: $(ln(y_t) - ln(y_{t-1}))/5 = (0.0017 * (26))/5$

Figure 1.10: Growth Effects Separated by Demographic and Non-demographic Variables by Region from 1960-2010



In this discussion I focus on the demographic effects, which can be seen as the red colored bars in Figure 1.10. To aid this discussion I have created Table 1.4, which shows the average of each demographic variable for each region over the 50-year study period.

Table 1.4: Average demographic variables by region between 1960-2010

	East Asia	Europe	Latin America	Middle East & North Africa	North America	Oceania	South Asia	Southeast Asia	Sub-Saharan Africa
Life Expectancy	73.1	74.9	68.1	63.4	74.2	69.1	58.9	65.5	51.5
Youth-Age Share (%)	25.4	19.7	37.0	39.4	27.5	33.2	40.6	36.1	44.0
Old-Age Share (%)	8.2	14.1	5.3	4.1	9.1	6.5	3.7	4.2	3.2
Change in Youth-Age Share (%)	-2.6	-1.1	-1.7	-1.6	-1.5	-1.3	-1.2	-2.0	-0.5
Change in Old-Age Share (%)	1.3	0.7	0.3	0.1	0.5	0.4	0.2	0.3	0.0

The first interpretation is that demographic effects are not significant contributors of economic growth for most regions. For East Asia, Europe, North America, Oceania and Southeast Asia, the demographic changes had positive impacts on economic growth, while for

Latin America, the Middle East & North Africa, South Asia and Sub-Saharan Africa the demographic changes had negative impacts. In general, the chart shows that for regions that have outpaced the world average economic growth (positive blue bar), the demographic impacts are also positive. In contrast, for regions that have underperformed against the world average economic growth (negative blue bar), the demographic impacts are also negative. From this, it can be inferred that more economically developed regions have potentially benefited over the last 50 years from population aging, while less economically developed regions have not.

I will not imply a direct causal relationship between population aging and economic growth. Instead, the amount of economic growth that can be accounted for by population aging will be discussed as a two-way relationship. The above results have supported the initial hypothesis, since it seems that more developed regions have benefited from population aging. There are various reasons that can explain why this result has come about.

Firstly, as a 'population ages' the youth-age share declines and the old-age share inclines. It can be seen in Table 1.4 that, in general, the more economically developed nations that have outpaced the world economic growth, including East Asia, Europe, North America, Oceania and Southeast Asia, have relatively lower youth-age shares and higher old-age shares. It is likely that this has pushed a large bubble of the population through the working-age share over the last 50 years. As such, more people in the workforce can explain the greater economic activity and thus greater growth in each of these regions.

The relationship extends to become 'two-way' when considering the impacts that greater growth and development have on the demographics of a nation or region. Until this point behavioral responses to both the aging population and greater economic development have not been considered. Firstly, it is generally the case that well-developed regions have lower fertility rates (contributing to population aging) than under-developed regions. As such, women in these economically developed regions have fewer children to care for in their homes. This is likely to have resulted in a significant increase in the number of women in the workforce, and also an increase in the number of hours spent working by both parents. This behavioral change supports the two-way relationship of economic growth and population aging, as they cause and impact each other.

Furthermore, retirement behavior is likely to have changed significantly in many of the countries in strong economically developed regions. Many people in these regions work well beyond the assumed 65-year retirement age, especially in North America. This is not surprising when considering the significant increase in life expectancy that has occurred in all of these regions. Table 1.4 shows that the regions that have been previously discussed as having higher economic growth than the world average, also have relatively higher life expectancy ages than under-performing regions.

The findings of this study are very much in line with previous papers on the topic of population aging. In particular, Bloom et al. (2010) found the impact of population aging on economic growth to be ambiguous due to various behavioral factors. These same behavioral responses are those which I have discussed and which inform the results of my research. In particular, both of our studies have found a negative relationship between the youth-age share and economic growth. That is, a declining youth-age share that has resulted from lower fertility rates has positive impacts on economic growth. For well-developed countries in this situation, having fewer in the youth-age share reduces the dependency of children on each working-age individual, thus draining less capital from the working-age share. In addition, Bloom et al. (2010) found that as the proportions of youth, working, and old age varied, the savings patterns of nations adjusted. This could also be a factor driving the results in this study, since regions that have a greater portion of their population either in the workforce or retired, are likely to have higher savings rates and more capital available for investment in human and capital stock.

Another possible factor explaining the above results is the increased investment in education per youth-age individual. This is likely due to the higher household income in these regions and also fewer people in the youth-age share. This reasoning also demonstrates the two-way relationship, since the smaller youth-age share allows for greater investment in human capital per person, which in turn enhances economic growth. This rationale was also discussed by Bloom et al. (2010). Furthermore, Fougère and Mérette (1999) found a similar result, although they used an Overlapping Generations Model to make their prediction.

VI. CONCLUSION

The overarching question this research seeks to answer is: How much of a region's economic growth can be accounted for by population aging? The most significant results relate to the direction of the demographic effect. Most prominently, it seems that more economically developed regions have potentially benefited from population aging, while less economically developed regions have not. I have provided an in-depth discussion of various explanations for this relationship, many of which are in line with previous studies. An important aspect of these findings is the two-way relationship between population aging and economic growth. This study does not imply a direct causal relationship between the variables.

There are possibilities for lines of further research beyond this study. Using the same methodology, it would be interesting to separate the countries differently. Instead of comparing the impacts of demographic structure changes by region, this could be done by income per capita level, or by government type. It is likely that the first of these studies will support the finding that well-economically developed countries have seen positive impacts from an aging population. Furthermore, it would be interesting to determine if the type of government and their policies relating to demographics, have common relationships with economic growth.

This current study will be important for future policy implications. Understanding the extent to which demographic changes have impacted economic growth over the past 50 years can help inform policy makers as they consider their projected demographic changes. In particular, since the major demographic change that has driven economic growth for well-developed regions has been the higher working-age share resulting from declining fertility rates, less-developed regions could expect similar impacts as they move through the development cycle. Furthermore, well-developed regions that have benefited from the increased working-age over the past fifty years must learn how to support the larger old-age share as their current enlarged working-age shares retire. A limitation of this research is that it does not empirically answer questions surrounding the causes of these demographic changes, but rather it provides likely explanations. Its main purpose is to examine how much population aging impacts economic growth in each region.

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